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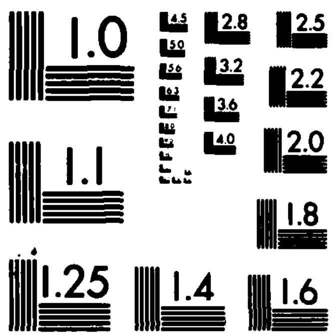

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QUANTUM SOLUTIONS AND STRANGE SOLUTIONS IN MANY-BODY PROBLEMS, FINAL REPORT

AFOSR-80-0257, July 1, 1981 - May 31, 1983

Principal Investigator: D.C. Mattis
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A summary is given of research accomplished and papers written under this grant. The research covered statistical and many-body theoretical physics, especially, new mathematical techniques for solving problems.

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INTRODUCTION

Research under this grant has produced several scientific publications, much significant research, and the formulation and elaboration of some original methods in the study of cooperative phenomena. We list papers which have been published, involving the work of the following personnel:

Dr. D.C. Mattis, P.I., Prof. of Physics

Dr. B. Sutherland, Faculty Associate

Dr. B.S. Shastry, Visiting Research Assistant Professor

Dr. J. Bruno, Postdoctoral Associate

Dr. R. Schilling, Visiting Scholar

Mr. S. Rudin

Miss R. Galler

and several undergraduate student assistants, programmers, etc.

D.C. Mattis and B. Sutherland: Strange Solution to Field Theories in One Spatial Dimension, J. Math. Phys. Phys. 22, 1692 (August 1981).

B. Sutherland and D.C. Mattis: Ambiguities with the Relativistic Delta-Function Potential, Phys. Rev. A24, 1194 (September 1981).

B.S. Shastry and D.C. Mattis: Theory of the Magnetic Polaron, Phys. Rev. B24, 5340 (November 1981).

D.C. Mattis: Phase Transition of Model Interacting Chains, Phys. Rev. B24, 6755 (December 1981).

D.C. Mattis and R. Schilling: Failure of Renormalization Group Method in Semiclassical Limit, J. Phys. C14, L729 (1981).

D.C. Mattis: Decay of Electron Waves in a Random Medium, Phys. Rev. Lett. 48, 1857 (1982).

D.C. Mattis and R. Galler: Odd Spin Cluster Interactions, Phys. Rev. B27, 2894 (1983).

R. Schilling and D. Mattis: Bound Exciton and Hole: An Exactly Solvable Three-Body Model in any Number of Dimensions, Phys. Rev. Lett. 49, 808 (1982).

R. Schilling and D. Mattis: Effect of Spin Variables and Exciton Motion on Ground State Properties of the Trion, Phys. Rev. B27, 3318 (1983).

R. Schilling and D. Mattis" Eigenstates of N Excitons and One Hole, Phys. Rev. B27, 4661 (1983).

J. Bruno and C. Vause: Equation of State for Random Uniaxial Dipolar Ferromagnets and Marginal Dimensionality, Phys. Rev. B25, 5918 (1982).

S. Rudin: One-Dimensional Backward Scattering Fermion Model with Built-in Cutoff (for Phys. Rev. D).

In addition, papers were presented at the International Conference LT 16 (Los Angeles, August 1981), appearing in the Journal Physica, and at the 2nd Rocky Mountain-Southwest Theoretical Physics Conference held in March 1982 in Salt Lake City (conference directed by D.C. Mattis), and 3rd Rocky Mountain-Sountwest Theoretical Physics Conference in March 1983 in Boulder (conference directed by A.O. Barut).

RESULTS

In addition to the published works listed above, our research has produced very satisfactory, indeed gratifying results in several areas. The emphasis is, in general, on the mathematics and physics of complex systems. We give some examples.

Exciton Physics. [Excitons are produced in insulators and semiconductors whenever light (photons) is absorbed. The decomposition of excitons into two charged carriers can be viewed as a principle mechanism in photovoltaics; the transport of excitons in organic molecules is a principal mechanism for photosynthesis. The condensation of excitons into a new collective condensed phase has been reported by experimentalists, and may lead to a new form of superfluidity and, ultimately, even superconductivity.] Our research has concentrated on charged excitons: "trions." These are bound states of 2 holes and 1 electron, or 2 electrons and 1 hole. We have an exact solution of this 3-body problem in a certain limiting case, the strong-binding limit, when the odd particle must be on the same site as one of the other two. We have also the exact solution of the many-exciton system in this same limit. Superconductivity, if it could occur in this system, would involve a large number of trions, but we have not solved the many-trion problem yet (except in 1 dimension, where we have the closed form solution of the two exciton and one charged particle problem). We are far from a complete understanding of the model as yet, but have developed an understanding for the mass ratios which are favorable to the formation of the complexes with a large number of particles. As an example, for the trion consisting of 2 holes and 1 electron, in our tight-binding limit, we have calculated that the maximum value for the ratio of effective masses m_e^*/m_n^* which will allow binding to occur is 0.3 in three dimensions. (The corresponding ratio for CuCl is 0.15 ± .05, whereas in Cu_2O it is approximately 1.0. Dielectric anomalies have been observed in the former, not in the latter, but it is too early to tell if trions are involved). A preliminary version of this work has been prepared for Physical Reviev Letters and has received the following referee's comments: "In this paper the authors are

concerned with a particular model for a 3-body problem. In principle, this represents a very interesting idea in a cross-disciplinary area which is suitable for Physical Review Letters...." After some clarifications, this paper was published, followed by a lengthy analysis in the Physical Review of the many-body problem in our model. We have in this model an application of pure mathematical physics to a field with great practical consequences.

Statistical Mechanics. The role of 3-, 5- and higher body-forces has not been studied at all in the literature. Such forces may affect the nature of phase transitions, of condensed matter, etc., but it has been traditional to study only binary forces (with or without the one-body forces represented by the chemical potential or an applied magnetic field in models of magnetism).

We have formulated a model in which clusters interact, and are discovering a variety of interesting results. It seems that in the magnetic model, a variety of new low-symmetry phases can appear in the ground state (absolute zero temperature). Where this will lead to the identification of new phase transitions, or explain phenomena which could not be understood on the basis of two-body forces, is something we are in the process of investigating and which will be treated in our next report. Certainly, the results so far have been as surprising as they have been interesting.

Field Theory. The paper by S. Rudin showed the importance of correct cut-off procedures in quantum field theory and the necessity of "counter-terms."

Documentation. The relevant (p)reprints are available in published journals, and have been sent to the program's manager, Dr. R.N. Buchal at AFOSR/NM where they are on file.

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